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EUVE Observations of VW Hydri in Superoutburst

CHRISTOPHER W. MAUCHE
Lawrence Livermore National Laboratory,
L-41, P.O. Box 808, Livermore, CA 94550

Abstract. *EUVE* observed the SU UMa-type dwarf nova VW Hydri in superoutburst for an interval of nearly 2 days in 1994 June and produced EUV light curves and the first EUV spectrum of this important CV.

1. Observations

VW Hyi was observed in superoutburst with *EUVE* from 1994 June 2.13 to 4.10 UT (RJD 9505.63 to 9507.60; RJD = JD − 2440000). The observations took place ≈ 3.5 days after the rise of the optical flux on $\approx$ May 29.5 UT and ≈ 2 days after the peak of the optical flux at $V \approx 8.5$ on $\approx$ May 31.0 UT. The Deep Survey photometer (70–170 Å) collected data for less than one day before being shut off because of the high count rate (~ 20 counts s^{-1}) induced in the detector by source photons. Earth occultations and standard settings on the pipeline reduction software presently limits the useful amount of spectrometer data to 4280, 4177, and 1075 s for the SW (70–180 Å), MW (145–370 Å), and LW (290–760 Å) spectrometers, respectively.

As measured by the Deep Survey photometer and the spectrometers, the EUV flux of VW Hyi was highly variable during the observations. The upper panel of Figure 1 shows the count rates recorded by the SW, MW, and LW spectrometers in the wavebands 80–170, 170–300, and 300–400 Å, respectively. Whereas the visual flux *fell* steadily from $V \approx 8.7$ to $V \approx 8.9$ during the observations, the EUV flux is seen to *increase*. On shorter time scales, the EUV flux variations, in particular the flux diminutions, are accompanied by distinct spectral variations. The lower panel of Figure 1 shows the ratio of the count rates in the 80–170 Å to 170–300 Å wavebands recorded by the SW and MW spectrometers as a function of time. Each diminution of the EUV flux is accompanied by a softening of the spectrum; just the reverse of the effect produced by variations in the column density.

Blithely ignoring these indications that the EUV spectrum of VW Hyi varied both in flux and shape during the observations, we constructed a net spectrum for the observation using data from each of the spectrometers. The result is shown in Figure 2. The SW, MW, and LW portions of the spectrum extend from 80–180, 160–360, and 300–420 Å, respectively, and are binned to 1, 2, and 4 Å, respectively; approxi-

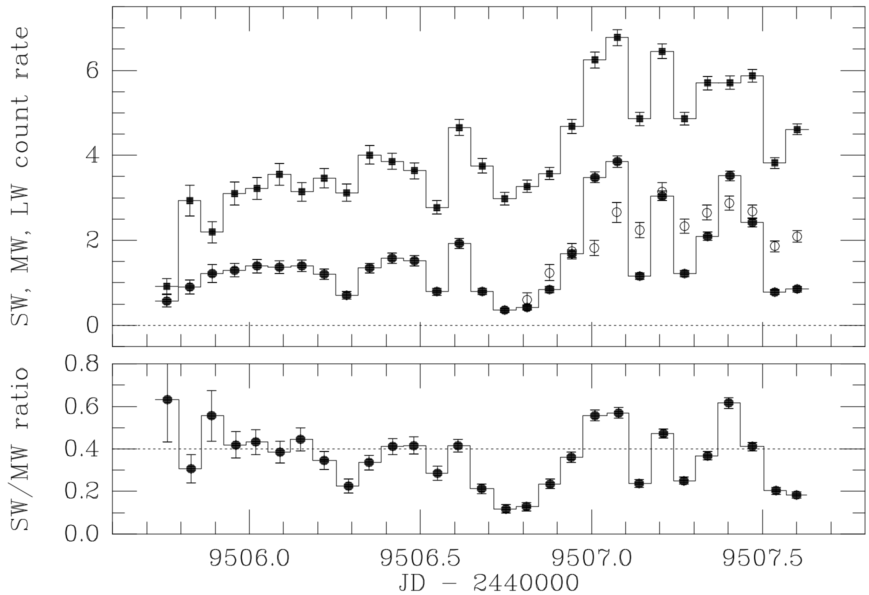

Figure 1. Upper panel: SW (100–170 Å: *filled circles*), MW (170–300 Å: *filled squares*), and LW (300–400 Å: *open circles*) count rate light curves of VW Hyi. Lower panel: SW over MW (hard over soft) count rate ratio.

mately twice the FWHM of the resolution of each spectrometer. There is residual signal in the LW spectrometer longward even of 420 Å, but this signal is most likely due to second-order flux; this effect is being investigated. The errors in the flux density due solely to counting statistics are everywhere less than 1×10^{-12} erg cm^{-2} s^{-1} Å^{-1}, and are typically less than half this amount.

2. Discussion

After years of speculation about its nature (e.g., van der Woerd, Heise, & Bateson 1986; Pringle et al. 1987; Mauche et al. 1991; van Teeseling, Verbunt, & Heise 1993), it is gratifying finally to see the EUV spectrum of VW Hyi. Many aspects of the spectrum are consistent with previous measurements. The fact that the spectrum peaks longward of 170 Å is consistent with the fact that in outburst the *EXOSAT* Al-Par filter count rate is higher than the 3000 Lex or 4000 Lex count rates. That the spectrum extends to yet longer wavelengths is consistent with the low neutral hydrogen column density ($\approx 6 \times 10^{17}$ cm^{-2}) measured by Polidan, Mauche, & Wade (1990). That the spectrum does not extend shortward of ≈ 100 Å (≈ 0.12 keV) is consistent with the nondetection in the 0.18–0.43 keV bandpass by *HEAO-1*

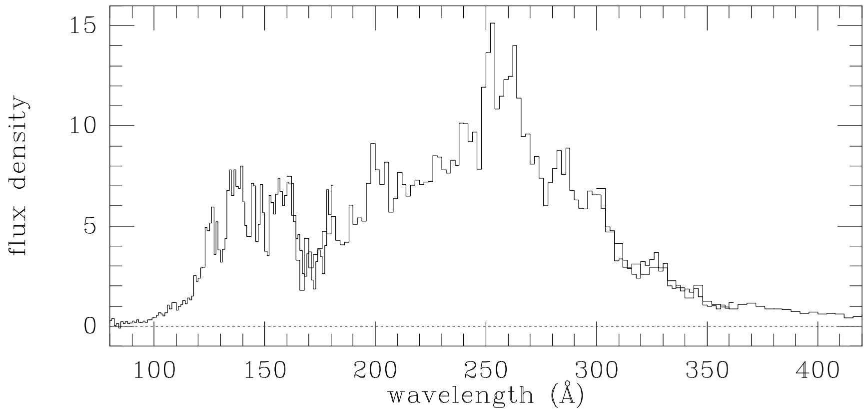

Figure 2. Net SW (80–180 Å), MW (160–360 Å), and LW (300–420 Å) spectra of VW Hyi. Units of flux density are 10^{-12} erg cm^{-2} s^{-1} Å^{-1}.

(Córdova et al. 1980) and with the *decrease* during outburst of the flux in the 0.1–2.4 keV bandpass measured by *ROSAT* (Wheatley et al. 1996). Inconsistent is the brightness of the spectrum. The observed 80–420 Å flux is 1.5×10^{-9} erg cm^{-2} s^{-1}, implying a luminosity of $7.7 \times 10^{32}\,(d/65\ \mathrm{pc})^2$ erg s^{-1}. For comparison, the luminosity of the accretion disk is ≈ 20 times higher (Mauche et al. 1991). The predicted *EXOSAT* Al-Par and 3000 Lex filter count rates are 28.3 and 15.5 counts s^{-1}, respectively. The highest measured *EXOSAT* Al-Par and 3000 Lex filter count rates appear to be 4.3 and 1.2 counts s^{-1}, respectively (van der Woerd & Heise 1987). Given the low net exposure on source, it is fortunate that VW Hyi was so bright during our observations.

It is fortunate also that the neutral hydrogen column density to VW Hyi is so low. Columns typical of other nearby CVs ($N_{\rm H} \gtrsim$ few $\times$ 10^{19} cm^{-2}; Mauche, Raymond, & Córdova 1988), would render VW Hyi nearly unobservable: at $N_{\rm H} = 3 \times 10^{19}$ cm^{-2}, the optical depth of the ISM is 1.1 at 100 Å, 3.2 at 150 Å, 6.5 at 200 Å. SS Cyg (Mauche, Raymond, & Mattei 1995) and U Gem (Long et al. 1995) both have higher columns, but are also intrinsically harder. If other, even nearby, CVs are as soft as VW Hyi, it will be hard to impossible to detect them in the EUV ($\lambda = 100$–912 Å).

As is the case with SS Cyg and U Gem, the EUV spectrum of VW Hyi belies simple interpretation. Consideration of the following options is instructive of the problems facing us.

(i) <u>A blackbody spectrum.</u> To produce so little flux shortward of ≈ 100 Å, the temperature of a blackbody must be $T \lesssim 1 \times 10^5$ K ($kT \lesssim 10$ eV). To extinguish the flux longward of ≈ 350 Å, the neutral

hydrogen column density then must be $N_{\rm H} \gtrsim 3 \times 10^{18}$ cm^{-2}, but such a model fails to reproduce the overall spectral distribution.

(ii) A modified blackbody spectrum. The ionization edges of C III–IV, N III–V, O III–IV, Ne II–IV, Mg III–IV, Si IV, S IV–VI, and Fe IV–VI all lie in this bandpass, but are not apparent in the spectrum. This result probably does not constrain irradiation of the white dwarf by a hard continuum spectrum, since such models produce edges at wavelengths below 100 Å (van Teeseling, Heise, & Paerels 1994).

(iii) The spectrum of an optically thin plasma. At $T \approx$ 1–few$\times 10^5$ K, the He II Lyman lines ($\lambda = 304, 256, 243, \ldots$ Å) and bound-free continuum ($\lambda < 228$ Å) are in emission, contrary to observations. At higher temperatures, particularly $T \gtrsim 5 \times 10^5$ K, the free-free continuum is weak, but strong emission lines begin to appear shortward of 100 Å.

Other processes likely affect the spectrum. The ISM and possibly the wind of VW Hyi will imprint a He II absorption edge at 228 Å onto the intrinsic spectrum. Measurement of, or upper limits on, such an edge will provide an estimate of the integrated column density of this ion. He I has autoionization resonances at $\lambda = 206, 195, 192, \ldots$ Å (Rumph, Bowyer, & Vennes 1994). The first such resonance may be responsible for the emission/absorption feature at 206 Å.

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